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Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

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ON NEW POSSIBILITIES FOR INCREASING THE EFFICIENCY OF CHARGED-PARTICLE ACCELERATORS

(Presented by Academician D. V. Skobeltsyn on 27 II 1957)

In the present article a new class of accelerators with time-constant magnetic fields is proposed—accelerators with stable contiguous particle trajectories. The magnetic system of such accelerators consists of three or more sectors with homogeneous magnetic fields.

Figure 1 shows one of the variants of the system considered. The magnet consists of four sectors having the same magnetic-field intensity $H_1 = H_2 = H_3 = H_4 = H$. In the gaps between the sectors the magnetic field is absent. In one of the gaps, at point A, through which pass the orbits for particles of any energy, an accelerating element of small dimensions is placed. Stability of particle motion is ensured by the action of the fringe magnetic field at the points of entry of particles into, and exit from, the magnetic sectors. The frequencies ω_z of the vertical and ω_r of the horizontal betatron oscillations depend on the rotation angle φ_1 of the particles in the first sector, on the inclination angle φ of the boundary of the second sector to the line of symmetry of the magnetic system, on the length of the rectilinear interval $l_{BB'} = 2rx$ between the symmetric halves of the magnetic system, on the length of the interval $l_{BG} = rkx$ between the points of intersection of the extensions of the boundaries of the magnetic sectors BC and DG with the boundary JG, parallel to the line of symmetry, and also on the adjustable angles γ_B and $\gamma_{B'}$ (not shown in Fig. 1), which are convenient to use for controlling the vertical and horizontal focusing of the particles. The stability region, determined as usual by the condition $|\cos\psi_{rz}| < 1$, proves to be very broad and, for example, in the case $\varphi = 40.5°$, $\varphi_1 = 84°$, $k = 0$, reaches the value $x = 0.77$. The perimeter L of the orbit is determined by the formulas

Fig. 1

$$L = L_0 + 2\pi r K; \qquad L_0 = 4rx\left[1 + k\,\frac{(1+\cos\varphi_1)\sin\varphi}{2\cos(\varphi+\varphi_1)}\right];$$

$$K = 1 - \frac{2(1+\cos\varphi_1)\cos(\varphi+\varphi_1/2)\sin(\varphi_1/2)}{\pi\cos(\varphi+\varphi_1)}.$$

In the case $L_0 = 0$, which provides a relation of the form $T = E,$ const between the period of revolution T and the total energy of the particle E, the stability region also has considerable dimensions.

The application of the proposed magnetic systems with mutually tangent trajectories of the accelerated particles in cyclotrons will make it possible to replace the dees by a small accelerating element located outside the magnetic field, to reduce substantially the gap between the poles of the magnet, to lower the power supply required for the magnet and the power of the radio-frequency system, and to increase the intensity of the accelerated-ion beam owing to improved focusing. Constancy of the ion revolution period can be ensured up to very high energies (despite the relativistic increase in mass) by introducing a definite dependence of the quantities φ, φ_1, and k on E. The number of possible resonances capable of building up betatron oscillations in the proposed magnetic system is much smaller than in Thomas-type systems ([1]), or in the sectored system with homogeneous magnetic fields in the sectors, proposed by the author jointly with M. S. Rabinovich ([2,3]) and R. S. Livingston ([4]).

The possibility of extracting ions from any cyclotron orbit will make it possible to vary the energy of the extracted beam (without retuning the radio frequency and without changing the magnetic-field strength) by parallel displacement of the extraction device in the interval CD (or in another interval) between sectors.

The magnetic system considered here should apparently also be used in phasotrons (synchrocyclotrons).

The proposed magnetic systems are of special importance for microtrons ([5,6]). The use of a system of the type considered will make it possible to reduce substantially the distance between the poles of the microtron magnet and to eliminate a very significant drawback of the microtron—the absence of stability—and should thereby lead to a sharp increase in the attainable energy and intensity of electron beams.

One of the important advantages of the microtron in comparison with other electron cyclic accelerators is the ease of injection and extraction of particles, owing to the considerable distances between neighboring orbits. In particular, the extraction of accelerated particles from microtrons of the type considered can be readily carried out from any of the microtron orbits by means of a parallel-displaced magnetic channel of length

$$l \simeq \frac{1}{2} r \left(\varphi + \varphi_1 - \frac{\pi}{2}\right).$$

In this case the extraction of particles takes place in one and the same direction, irrespective of the orbit from which the particles are taken.

The use of sectored magnetic systems with stable mutually tangent trajectories of the accelerated particles should lead to the further development of microtrons and to an expansion of the range of their applications as injectors for synchrotrons, as generators of very short ($\tau < 10^{-11}$ sec.) powerful electron pulses and generators of microwaves, and also as generators of γ-rays, effective sources of neutrons, etc.

In conclusion, the author expresses gratitude to V. I. Veksler for his interest in this work, to M. S. Rabinovich for his attention to the work and valuable advice, and to A. A. Kolomenskii for a useful discussion.

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CITED LITERATURE

1. L. H. Thomas, *Phys. Rev.*, **54**, 580, 588 (1938).
2. E. M. Moroz, DAN, **108**, No. 3, 346 (1956).
3. E. M. Moroz, M. S. Rabinovich, *CERN Symposium, Proc.*, Geneva, **1**, 1956, p. 547.
4. R. S. Livingston, *Industrial and Engineering Chemistry*, **48**, (8), 1231 (1956).
5. V. I. Veksler, DAN, **43**, No. 8, 346 (1944).
6. E. M. Moroz, DAN, **106**, No. 6, 986 (1956).

Note: Figure translations are in progress. See original paper for figures.